

Heavy ion track length in muscovite mica

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Abstract : Muscovite mica is used for various purposes like production of high throughput-microfilters as well as to identify products of nuclear reactions in the forward direction. For these purposes a knowledge of the total etchable track lengths of several heavy ions under optimum etching conditions is essential. Here we present our results obtained for maximum etchable track lengths of ^{40}Ar (18.56 MeV/u), ^{132}Xe (17.0–5.8 MeV/u), ^{208}Pb (17.1 MeV/u) and ^{238}U (8.3 and 13.7 MeV/u). Experimental track lengths are compared with the theoretical values derived from the computer code 'RANGE' and a fairly good agreement has been observed.

Keywords : Maximum etchable track length, muscovite mica, ^{40}Ar , ^{132}Xe , ^{208}Pb , ^{238}U .

PACS Nos : 29.40.-n, 29.70.-e

1. Introduction

Utilization of solid state nuclear track detectors for various purposes especially for particle identification and production of microfilters requires knowledge of the damage created by different ionizing radiations. In recent years, muscovite mica has been successfully used in the production of high throughput-microfilters (Vater 1988 and Guo Shi-Lun et al 1988) using heavy ion beams. However, for production of high quality mica filters of varied thickness, it is of utmost importance to study the total etchable track lengths of several heavy ions under optimum etching conditions. The maximum etchable track lengths in muscovite mica for ^{132}Xe (17.0–5.8 MeV/u), ^{208}Pb (17.1 MeV/u) and ^{238}U (8.3 and 13.7 MeV/u) were determined. The maximum etchable track length for ^{40}Ar could not be determined for reasons which have been discussed under Section 3. The experimental track lengths were also compared with the theoretical values derived from the computer code 'RANGE' (Dwivedi 1988). The measuring accuracy and the significance of the experimental results are discussed.

2. Experimental

2.1. Irradiation :

Background free circular pieces of muscovite mica [$\text{KAl}_2(\text{OH})_2\text{Si}_3\text{AlO}_{10}$] of thickness $\sim 500 \mu\text{m}$ were exposed to well collimated beams of some heavy ions of

different energies at UNILAC, GSI, Darmstadt. The different heavy ions used and their energies are as follows – ^{40}Ar (18.56 MeV/u), ^{136}Xe , (5.8, 7.4, 9.2, 12.0, 14.7 and 17.0 MeV/u). All irradiations were done at an angle of 45° to the surface of the detector with an optimum flux of $10^4/\text{cm}^2$.

2.2. Etching conditions :

All the irradiated mica pieces were etched in 20% HF at $55 \pm 1^\circ\text{C}$ till the latent tracks were completely developed. It may be referred to here that mica detectors have been etched by 40–48% HF (Dwivedi and Mukherji 1979a, Fleischer et al 1964). But in the present work we have found that a dilute solution of HF (20%) helps to develop more uniform cylindrical tracks in mica with much less spurious background at the surface. The etching time was suitably adjusted to get fully etched tracks in each detector.

2.3. Measurement of track length :

After etching, the samples were washed and dried. Projected lengths of tracks were measured with a Leitz 'Laborlux D' optical microscope at 625X magnification ; the track diameters were measured at 1562.5X magnification.

Mica shows anisotropy in bulk etching. The bulk etch rate along the surface is nearly 20 times larger than the rate normal to the surface. Therefore, the loss of track length due to surface etching is negligible and no etching corrections are required in mica. The maximum etchable track length (L) can be calculated from the projected lengths (l) simply by using the following formula

$$L = l \sec \phi \quad (1)$$

where ϕ is the angle of incidence of the ion beam.

Length of several hundred tracks of each ion were measured in order to obtain more representative and statistically rich data.

2.4. Error analysis :

The accuracy in track measurement at a magnification of 625X and 1562.5X was found to be $\pm 1.2 \mu\text{m}$ and $\pm 0.44 \mu\text{m}$ respectively. The standard deviations in track length was obtained from distribution curves and were found to vary between 1.7 to $2.34 \mu\text{m}$. The overall error in track length distribution range from 2.0 to $2.6 \mu\text{m}$.

3. Results and discussion

The track length in an SSNTD is just that part of the range of the heavy ion over which the actual energy loss rate of the ion remains above a threshold value which is characteristic of the detector material and is represented by $(dE/dX)_0$. For mica,

the value of $(dE/dX)_0$ was found to be nearly $13.0 \text{ MeV mg}^{-1} \text{ cm}^2$ (Dwivedi and Mukherji 1979b, Fleischer *et al* 1965). The energy-loss rate of ^{132}Xe , ^{208}Pb and ^{238}U in mica remains higher than the critical value for the entire energy region whereas for ^{40}Ar ions with energy above 7.0 MeV/u , the energy-loss rate is less than the critical value. Since ^{40}Ar ions with energy 18.56 MeV/u were used in the present work, therefore, no etchable tracks were observed at the mica surface. However, on etching the mica samples after cleaving into thin sheets, some partially etched tracks could be observed but the maximum etchable track lengths could not be measured for 18.56 MeV/u ^{40}Ar -ions in mica.

The maximum etchable track lengths of ^{132}Xe at six different energies between 5.8 to 17.0 MeV/u , ^{208}Pb at 17.1 MeV/u and ^{238}U at 8.3 and 13.7 MeV/u were measured in mica. Figure 1 shows a plot of the maximum etchable track lengths

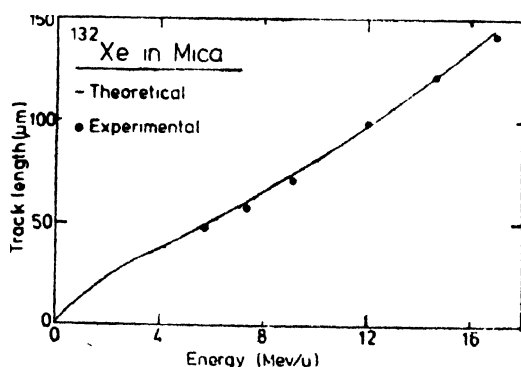


Figure 1. A plot of experimental track lengths at different energies for ^{132}Xe ions in mica alongwith theoretical values obtained from the computer code 'RANGE' (Dwivedi 1988).

at different energies for ^{132}Xe in mica. The solid circles are our experimental data whereas the curve represents the theoretical values derived from the computer code 'RANGE' (Dwivedi 1988). Figure 2 shows the similar plot for ^{238}U in mica. For

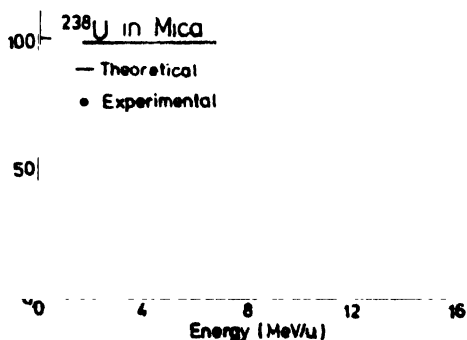


Figure 2. A plot of experimental track lengths at different energies for ^{238}U ions in mica alongwith theoretical values obtained from the computer code 'RANGE' (Dwivedi 1988).

²⁰⁸Pb we have measured track lengths only at energy 17.1 MeV/u, therefore a track length distribution curve is constructed and shown in Figure 3. The mean track length was found to be $125.2 \pm 2.6 \mu\text{m}$.

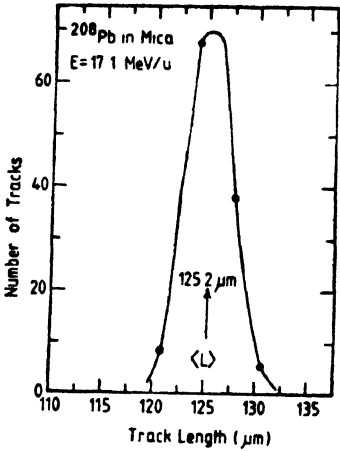


Figure 3. Track length distribution curve for 17.1 MeV/u ²⁰⁸Pb in mica. The most probable track length was found to $125.2 \pm 2.6 \mu\text{m}$.

Table 1 summarizes our experimental data on maximum etchable track length of ¹³²Xe, ²⁰⁸Pb and ²³⁸U ions in mica alongwith the corresponding theoretical

Table 1. Maximum etchable track lengths of ¹³²Xe, ²⁰⁸Pb and ²³⁸U in muscovite mica.

Ion	Energy (MeV/u)	Maximum etchable track length (μm)	
		Experimental (Present work)	Theoretical*
¹³² Xe	5.8	50.0 ± 2.4	49.0
	7.4	63.3 ± 2.0	60.5
	9.2	76.0 ± 2.6	75.2
	12.0	99.5 ± 2.6	98.0
	14.7	121.9 ± 2.6	122.8
	17.0	141.0 ± 2.6	145.0
²⁰⁸ Pb	17.1	125.2 ± 2.6	122.1
	8.3	64.5 ± 2.4	65.0
	13.7	104.0 ± 2.6	100.0

*from computer code 'RANGE' (Dwivedi 1988).

values obtained from computer code 'RANGE' (Dwivedi 1988). The present experiment further supports the earlier investigations (Dwivedi et al 1986, Saxena et al 1987 and Ghosh et al 1988) that the stopping power equations of Mukherji and

coworkers (Mukherji and Srivastava 1974, Srivastava and Mukherji 1976, Mukherji and Nayak 1979, Dwivedi and Mukherji 1979b) which are used in computer code 'RANGE', predict the most reliable values of heavy ion track lengths in complex solids.

Acknowledgments

We wish to thank Dr R Spohr, Dr J Vetter and Dr (Mrs) C Trautmann of UNILAC, GSI, Darmstadt for providing irradiation facilities. We also thank the German Agency for technical cooperation (DGZ), FRG for an equipment grant.

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